CITY OF SUMAS
CLASS II INSPECTION
SEPTEMBER 23 - 25, 1991

by
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ABSTRACT

A Class II Inspection was conducted at the town of Sumas wastewater treatment plant on September 23-25, 1991. The inspection found a plant which was performing quite well, achieving 98 percent removal of BOD_5 and TSS, as well as nitrification and denitrification. Copper, lead, and zinc were detected, but at concentrations below water quality standards. No toxicity was indicated by bioassays run on effluent. The present sampling procedure involving 8-hour hand composites is not always producing representative samples, and should be replaced.

INTRODUCTION

Ecology conducted a Class II Inspection at the town of Sumas on September 23-25, 1991. The inspection was conducted by Norm Glenn and Rebecca Inman, members of the Watershed Assessments Section of the Environmental Investigations and Laboratory Services (EILS) Program. Lawrence Silvas, the town's wastewater treatment plant (WWTP) operator, provided assistance. A concurrent Total Maximum Daily Load (TMDL) study was conducted by EILS in the Sumas River (Cusimano, in prep.).

Objectives of the inspection included:

1. Verify compliance with NPDES permit limits;
2. determine loadings and WWTP removal efficiencies;
3. determine whether selected metals are present in effluent in toxic amounts;
4. characterize toxicity in the effluent by using bioassays; and
5. evaluate permittee's self-monitoring by reviewing sampling, flow measuring procedures, and by conducting sample splits.

Figure 1 is an area map showing the location of the Sumas WWTP. The town relied on individual septic tank systems until 1973 when a sanitary sewer system and secondary treatment plant were installed. The system serves a population of about 750 people. There are no significant industrial sources. The town is authorized to discharge treated and chlorinated wastewater to the Sumas River year-round under NPDES permit No. WA 002049-4(M) issued January 28, 1985. Self-monitoring under the permit consists of 8-hour grab composites for BOD_5 and TSS taken twice per month for analysis at the Lynden WWTP laboratory.

Figure 2 is a plant schematic. Influent is intermittent, subject to automatic operation of the upstream pump station/wet well. The treatment process consists of comminution, aeration in an oxidation ditch, and sedimentation in a secondary clarifier. Effluent is then chlorinated for disinfection prior to discharge through a 5000 ft. outfall line to the Sumas River. The town's stormwater enters the same outfall line about 200 ft. downstream from the WWTP. Sludge is aerobically digested with air provided by a mechanical, mixer-aerator on a timer. Disposal is to farmland during the dry season. Two tanks with a combined capacity of 30,000 gallons hold digested sludge during the wet season.

METHODS

A variety of different composite, grab, and grab-composite samples were collected:

- twenty-four hour composite samples of influent and effluent;
- grab samples of influent and effluent;
- grabs of mixed liquor suspended solids (in-process) from the oxidation ditch;
- grabs of return activated sludge (RAS) from the return line;
- grabs of sludge from the digester; and
- 2 grab-composite samples of effluent for bioassays.

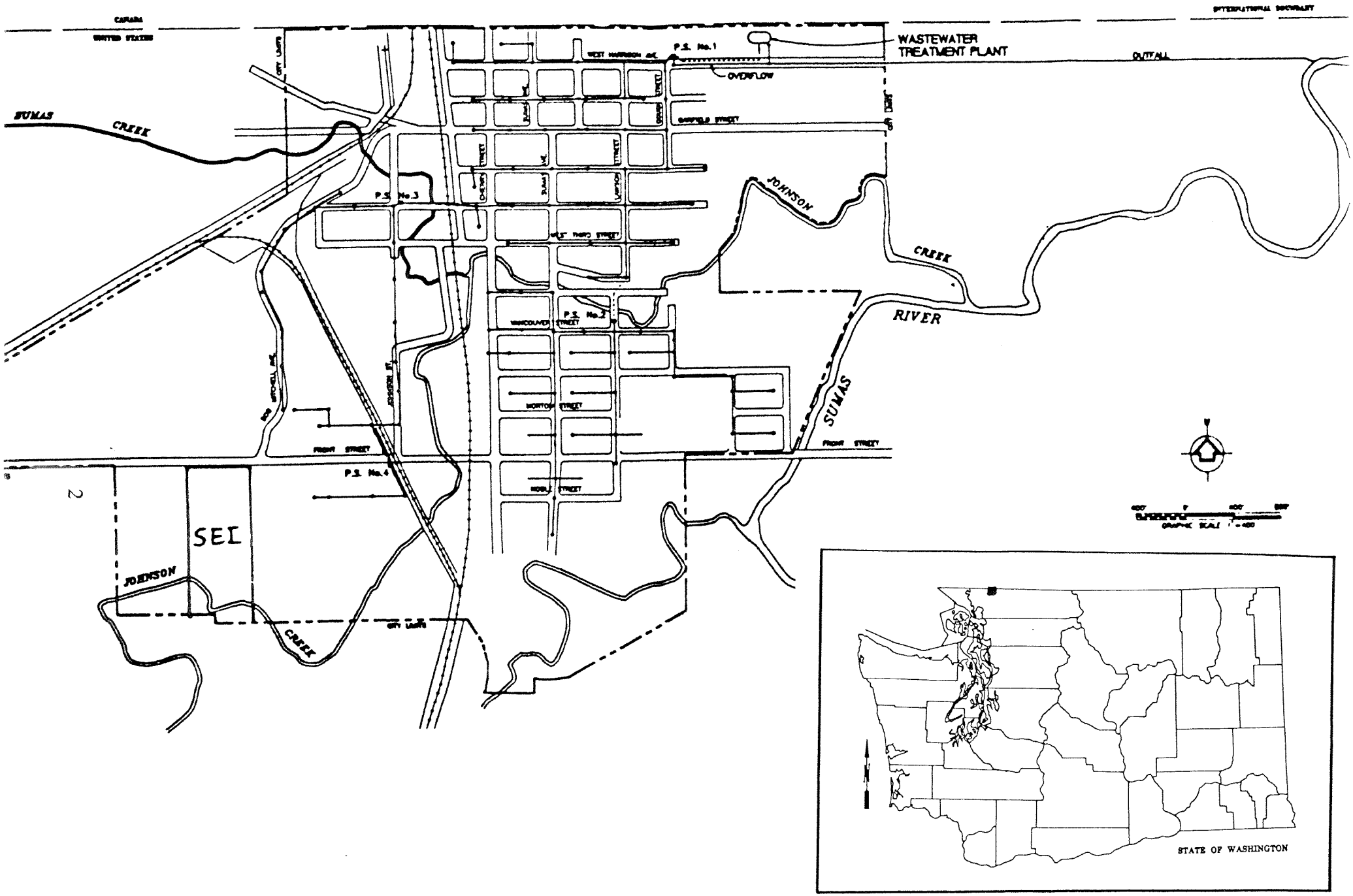

Figure 1. Location Map - City of Sumas WWTP, 9/91.

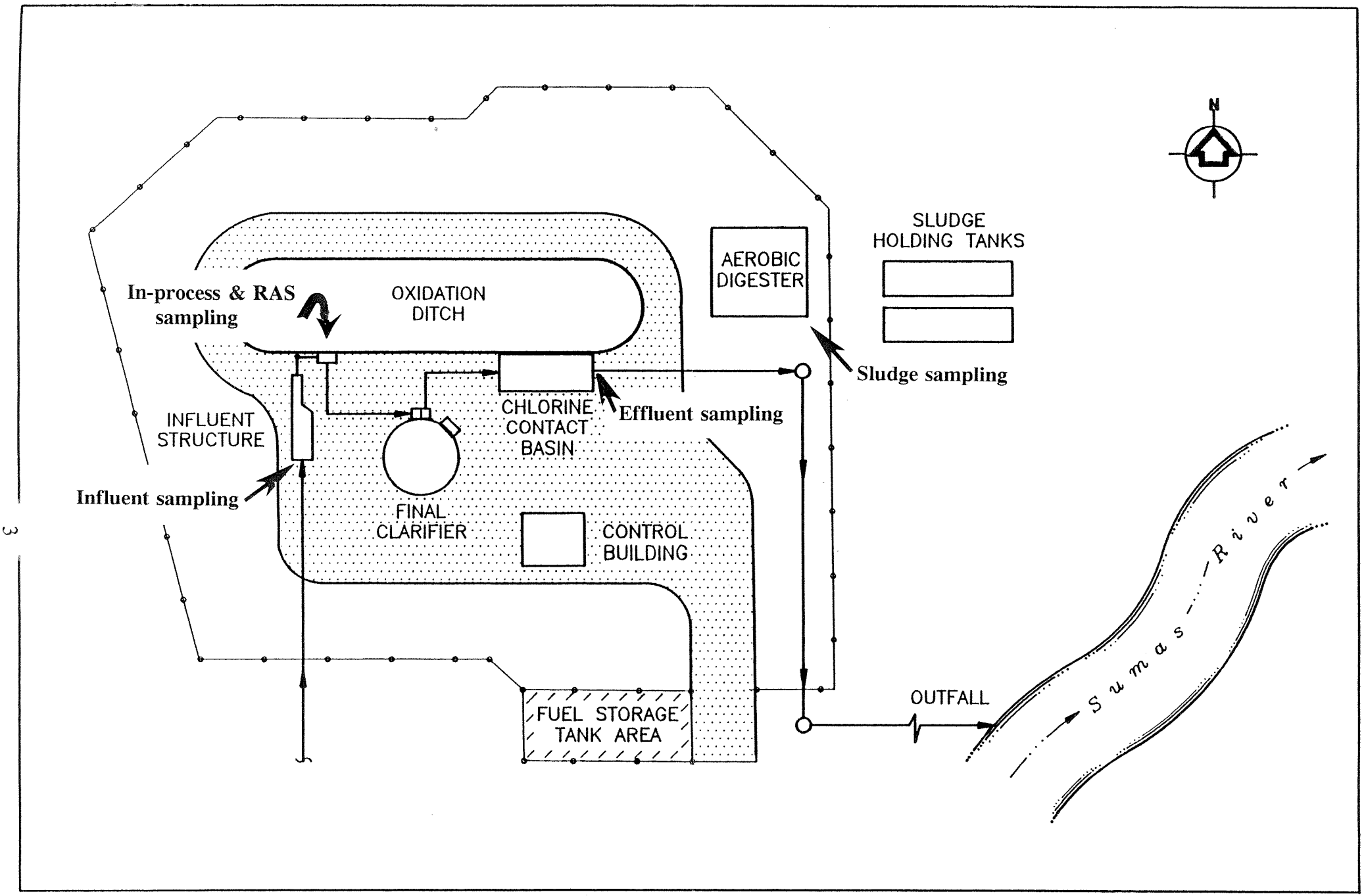

Figure 2. Plant Schematic - City of Sumas WWTP, 9/91.

The sampling schedule and list of parameters analyzed are shown in Table 1.

Discharger influent and effluent sampling points appeared to be as representative as possible and were used by Ecology also. [Note: representativeness of influent which arrives intermittently through a vertical standpipe will always be questionable.] The operator's sample consisted of 3 grabs composited over an 8-hour working day. Ecology composites were time proportional; our ISCO samplers collected approximately 260 mL every 30 minutes.

Sampling locations are shown in Figure 2. Influent arrives at the headworks through a vertical standpipe. The sampling tube for the compositor was inserted into the standpipe to ensure that sufficient influent would always be available. Grabs were taken when wastewater was flowing from the standpipe.

Effluent was sampled from the chlorine contact basin just before entering the outfall line. Both composites and grabs were collected on the day following collection of influent samples in an attempt to sample the same slug of wastewater as it moved through the plant. The in-process sample was collected directly from the oxidation ditch, while RAS was sampled at the same spot but directly from the return discharge line.

Sludge was sampled from a spigot on the outflow line of the digester. Two grab-composites were taken for whole-effluent toxicity testing (bioassays); the second was refresher water. Fecal coliform and streptococci bacteria were included in analyses of influent, effluent, and sludge samples collected in order to evaluate the reduction of pathogens in the treatment process prior to land disposal of sludge. The city of Lynden conducts laboratory analyses for the Sumas WWTP on prearranged days set by contract. The inspection did not fall on one of these days, so neither aliquots of Ecology nor Sumas samples were analyzed by a discharger designated lab.

All sampling equipment was cleaned before use by washing with non-phosphate detergent and rinsing successively with tap water, ten percent nitric acid, deionized water (three times), pesticide-grade methylene chloride, and pesticide grade acetone. Collection equipment was air-dried and wrapped in aluminum foil until used. All sample containers destined for the Manchester Laboratory were placed on ice and shipped within 24 hours. Appendix A is a listing of the analytical methods used for analysis of parameters.

The influent Parshall flume was inspected for its physical condition and appropriate dimensions. Instantaneous flow determinations were made based on measured head for comparison to an analog readout in the control room.

DATA QUALITY ASSURANCE

Laboratory quality assurance and quality control (QA/QC) methods are described by Huntamer and Hyre (1991). Recommended holding times were met for all analyses performed except some BOD_5 samples and one fecal coliform sample, as noted on Table 2. All data which exceeded

Table 1 - Sampling Times and Parameters Analyzed - Town of Sumas, 9/91.

Parameter	Location: / Type: / Date: / Time: / Lab Log #: 3980-	Inf-S gr-comp 9/23 8 hr 80	Inf-E comp 9/23-24 24 hr 81	Inf-1 grab 9/23 late pm 90	Inf-2 grab 9/23 late pm 82	Inf-3 grab 9/24 late am 83	In-process grab 9/24 pm 84	Eff-S gr-comp 9/24 8 hr 85	Eff-E comp 9/24-25 24 hr 86	Eff-1 gr-comp 9/23 6 hr 93	Eff-2 grab 9/24 early pm 87	Eff-3 gr-comp 9/25 6 hr 91	Eff-4 grab 9/25 early am 88	Sldg-1 grab 9/23 late pm 92	Sldg-2 grab 9/24 pm 89	RAS grab 9/24 am 94
GENERAL CHEMISTRY																
Turbidity									E		E		E			
Conductivity			E		E	E	E		E		E		E			
Alkalinity			E		E	E	E	S	E		E		E		E	
Hardness									E		E		E			
Chloride									E		E		E			
SOLIDS (4)																
TS			E				E		E						E	E
TNVS			E				E		E						E	E
TSS		S	E		E	E	E	S	E		E		E			
TNVSS			E				E		E							
% Solids															E	
% Volatile Solids															E	
BOD5		S	E		E	E	E	S	E		E		E			
TOC									E						E	
NUTRIENTS																
NH3-N			E		E	E			E		E		E			
NO2+NO3-N			E		E	E			E		E		E			
Nitrogen - Total(TPN)			E		E	E			E		E		E			
Phosphorous - Total			E		E	E			E		E		E			
Phosphate - Ortho									E		E		E			
Oil and Grease (water)											E		E			
F-Coliform MF											E		E			
F-Coliform MPN				E						E^				E		
F-Streptococci MPN				E						E^				E		
METALS (Total rec)																
cadmium									E							
copper									E							
lead									E							
zinc									E							
BIOASSAYS																
Salmonid (acute 65%)										E						
Salmonid (acute 100%)										E						
Daphnia pulex (acute)										E		E*				
Ceriodaphnia (chronic)										E		E*				
FIELD OBSERVATIONS																
Temp		S	E		E	E	E	S	E		E		E	E	E	
pH		S	E		E	E	E	S	E		E		E	E	E	
Conductivity		S	E		E	E	E	S	E		E		E			
D.O.							E				E		E			
Chlorine										E	E		E			

* Refresher water for bioassays.

E Samples collected and analyzed by Ecology.

^ Grabs only.

S Samples collected by Sumas; analyzed by Ecology.

Table 2 - Results of General Chemistry and Metals Analyses - Town of Sumas, 9/91.

Parameter	Location:	Inf-S	Inf-E	Inf-1	Inf-2	Inf-3	In-process	Eff-S	Eff-E	Eff-1	Eff-2	Eff-4	Sldg-1	Sldg-2	RAS
	Type:	gr-comp	comp	grab	grab	grab	grab	gr-comp	comp	gr-comp	grab	grab	grab	grab	grab
	Date:	9/24	9/23-24	9/23	9/23	9/24	9/24	9/24	9/24-25	9/23	9/24	9/25	9/23	9/24	9/24
	Time:	8 hr	24 hr	1615	1530	1015	1020	8 hr	24 hr	6 hr	1630	0900	1635	1815	1150
	Lab Log #: 3980-	80	81	90	82	83	84	85	86	93	87	88	92	89	94
GENERAL CHEMISTRY															
Turbidity (NTU)											1.7	1.7			
Conductivity (umhos/cm)			708		806	705	651		530		532	511			
Alkalinity (mg/L CaCO3)			253		240	223	292	145	149		145	148		406	
Hardness (mg/L CaCO3)									131		131	129			
Chloride (mg/L)									39.4		39.4	38.1			
SOLIDS (4) (mg/L)															
TS			618				3660		346					18010	7690
TNVS			295				993		289					4090	1820
TSS		208	194		148	187	NAF	3	4		4	3			NAF
TNVSS			22				NAF		1						NAF
% Solids														1.8	
% Volatile Solids														1.4	
BOD5 (mg/L)		145	230		245 OHT	222 OHT	<60 OHT	5 OHT	<4		5	4			
TOC (water mg/L)									7.52		7.34			4700	
NUTRIENTS															
NH3-N			21.3		22.1	18.7			0.2		0.1	0.1			
NO2+NO3-N			1.3		1.1	1.4			2.8		4.0	1.8			
Nitrogen - Total(TPN)			36.8		45.8	39.0			4.1		5.2	3.0			
Phosphorous - Total			8.5		11.0	8.5			6.6		13.2	6.2			
Phosphate - Ortho									6.7		6.6	6.4			
Oil and Grease (mg/L)											<0.5	<0.5			
F-Coliform MF (#/100ml)											1100 OHT	39			
F-Coliform MPN (#/100ml)				>1,600,000						13,000^			900,000		
F-Strep MPN (#/100ml)				900,000						500^			1,600,000		
METALS (ug/L)*															
cadmium									2.0 U						
copper									4.9 P						
lead									1.3 P						
zinc									72.3						
FIELD OBSERVATIONS															
Temp (C)					18.7	18.5	18.1				19.2	19.3		18.1	
pH (S.U.)		8.03			8.09	8.29	7.08	7.44			7.25	7.11		5.89	
Conductivity (umhos/cm)		720	580		680	675	520	525	525		525	505			
D.O (mg/L)							0.2					1.85			
Chlorine (mg/L)															
Free								<0.1			0.1	<0.1			
Total								<0.1			0.1	0.2			

* Total recoverable.
^ Grab only.
OHT Over holding time.
NAF Not analyzed for.

U Analyte was not detected at or above the reported limit.
P Analyte was detected above the instrument detection limit but below the established minimum quantitation limit.

holding times have been interpreted with caution. One total phosphorus result from the effluent was high (13.2 mg/L) compared to two other closely aligned results ($\approx$ 6.5). However, it has not been treated as an outlier. Matrix spike recoveries and relative percent difference duplicate spikes (a measure of precision) were within acceptable QC limits.

Rainbow trout and *Daphnia* (water flea) bioassays were conducted on effluent and laboratory controls containing dilution water. The trout control met the protocol requirement of 90 percent survival for acute tests (EPA,1985). A second trout and *Daphnia* control survivals met 80 percent requirements specified in the protocols for 7-day chronic testing (EPA, 1989a).

RESULTS AND DISCUSSION

Flow

Physical measurements taken of the Parshall flume showed that the dimensions were correct and that the float which senses water level was properly positioned. Depth of water passing through the flume was measured during one of the intermittent surges; the depth corresponded to a flow of 0.49 MGD (ISCO, 1985). The instantaneous, analog flow meter in the control room read 0.44 MGD at the same instant, which seems accurate enough given the intermittent nature of the flow. Totalizer readings taken on September 23 and September 24 (exactly 24 hours apart) gave a daily average flow of 0.087 MGD.

Wastewater Characteristics and Comparison to NPDES Permit Limits

Results from fecal coliform samples taken on the first and second days of the inspection were high (Table 2). One sample had been analyzed using the Most Probable Number (MPN) method and one using membrane filter (MF), the method specified in the permit. Both counts exceeded permit limits. Field observations of chlorine residues indicates quite low numbers. Detention time in the contact chamber was probably under 30 minutes and could have contributed to the problem. However, state design criteria allow a minimum of 20 minutes detention for a peak daily flow, which may have been occurring at 1630 hours when the fecal samples were taken (Ecology, 1985). The most logical reason would be erratic performance by the chlorination equipment.

However, the data should be used with caution because the MF result is qualified (OHT) and the MPN method tends to give higher values in chlorinated effluent. The result of a third sample taken on Day 3 using MF was acceptable. All other conventional parameters indicated a well-treated, high quality effluent which met permit limits.

Metals were analyzed using the total recoverable method. Several were detected in the effluent: namely, copper, lead, and zinc. Concentrations of copper and lead were both estimated due to responses below the accurate quantitation limit. All three concentrations were below freshwater acute and chronic water quality criteria, due in part to the relatively hard water.

Wastewater Loading and Treatment Efficiency

Table 3 shows that BOD_5 influent loading is about 167 lbs/day, which is approaching 85 percent of design capacity for this WWTP. To conform with the stipulation in their permit, a plan and schedule for continuing to maintain adequate treatment capacity should be submitted in the near future. However, this results in an aerator loading of only about 12 lbs BOD/10^3 ft^3); 10 - 25 is considered acceptable (Ecology, 1985). TSS loading was about 141 lbs/day. Effluent loading to the Sumas River was 3 lbs/day for both pollutants--well below permit limits for weekly and monthly average loadings. Very high removal efficiencies (98%) were being achieved for both BOD_5 and TSS; pH was fine. The average daily flow rate obtained during the inspection was used to calculate the mass loadings.

Effluent ammonia, nitrate-nitrite, total persulfate nitrogen (TPN), and alkalinity concentrations indicated that the WWTP was nitrifying and denitrifying at the time of the inspection. Effluent total ammonia concentration (0.192 mg-N/L) was much less than the freshwater acute and chronic water quality criteria (EPA, 1986). The acute criterion is 15.8 mg/L as N; the chronic criterion is 1.23 mg/L as N (pH = 7.25, T = 20°C). Effluent total nitrogen concentration ($\approx$ 4 mg/L) was excellent, resulting from plant operation which produced 90 percent removal of nitrogen. Concentrations of phosphorus in the effluent were somewhat higher than is typically found in municipal wastewater.

The oxidation ditch is operated in the extended aeration mode. Settleability of solids in the clarifier is monitored closely, and the operator wastes sludge to the digester based on analysis of this parameter. There is no way of measuring flow rate through the RAS or waste activated sludge (WAS) line. There is no metering device, and the valve on the 4 inch RAS line has been partially closed. The pump (which serves both lines) works on a 4 - 8 minute ON/OFF cycle and averages "24 minutes ON/36 minutes OFF" every hour around the clock pumping RAS. The only exception is the $\pm$15 minutes per week that flow is switched by the operator to the WAS line.

One objective of the inspection was to do a number of wastewater loading calculations and compare them to design criteria. However, solids (4) analyses were not completed on the in-process and RAS samples by the laboratory. Therefore, volatile suspended solids concentrations for these two locations, which are necessary data for an entire suite of calculations, could not be determined.

Recent Technology Transfer guidance suggests a sludge age of at least 20 days for extended aeration and oxidation ditch treatment, which are referred to as No Primary/Long Sludge Age (NP/LSA) wastewater treatment (EPA, 1989b). Sludge age is one of the parameters which could not be calculated because of the incomplete solids (4) analyses.

Table 3. Comparison of Inspection Results to NPDES Permit Limits – Sumas WWTP, 9/91.

	NPDES Permit Limits		Inspection Data		Plant Loading			
Parameter	Monthly Average	Weekly Average	Ecology Composite	Grab Samples	Design Criteria	85% of DC	Inspection Results	%of DC
Influent BOD5								
(mg/L)			230	245;222 OHT				
(lbs/d)					200	170	167	83
Effluent BOD5								
(mg/L)	30*	45	<4	5;4				
(lbs/d)	31	46					3	
(% removal)							>98	
Influent TSS								
(mg/L)			194	148;187				
(lbs/d)					200	170	141	70
Effluent TSS								
(mg/L)	30*	45	4	4;3				
(lbs/d)	31	46					3	
(% removal)							98	
Fecal Coliform				1,100 OHT; 39				
(#/100 ml)	200	400		13,000**				
pH (S.U.)	6.0≤pH≤9.0			7.2				
Flow (MGD)					0.124	0.105	0.087	70

* or 15% of the respective influent concentrations, whichever is more stringent.

** Most Probable Number (MPN) procedure used.

OHT Over holding time.

Sludge Loading and Treatment Efficiency

Federal regulations require that all sludge which is land applied be treated to reduce pathogen levels and volatile solids which can be attractive to disease vectors such as rodents, flies, and mosquitoes. Aerobic digestion is defined in the regulation as a process "conducted by agitating sludge with air or oxygen to maintain aerobic conditions at residence times ranging from 60 days at 15°C (59°F) to 40 days at 20°C (68°F), with a volatile solids reduction of at least 38 percent" (EPA,1989b).

In those cases where separate aerobic digestion follows an oxidation ditch process, the requirement to achieve a volatile solids (VS) reduction of 38 percent applies to the combination of the separate digester and oxidation ditch process. Reduction can be determined through a mass balance on VS using the influent wastewater, the final sludge product, and the effluent wastewater (EPA, 1989b).

Adequate virus and bacterial pathogen reduction can be demonstrated by measuring fecal coliform and fecal streptococci concentrations. The geometric mean of the concentrations must have an average $\log_{10}$ density (NO./g TSS) of less than 6.0 in the digested sludge. Calculations for decision making should be based on data from at least nine sludge samples collected over a period of time to account for sampling and laboratory variability.

Rough calculations suggest that the volatile solids reduction was about 60%, well above the minimum of 38%. No determination was made of whether the federal requirements for pathogen reduction were being met. Both the volatile solids and pathogen reduction calculations should be repeated by the permittee using flow weighted average data collected over a one- or two-month period to determine if the sludge is adequately stabilized for land application.

Effluent Bioassays

No toxicity was indicated by the four acute and one chronic bioassays run on the effluent (Table 4). LC_{50}s and the NOEC indicated either no mortality or results that were statistically insignificant.

Comparison of Laboratory Results

An aliquot of a grab-composite collected by the plant operator was analyzed for TSS and BOD_5 along with the Ecology samples. Laboratory results are shown on Table 2 under the 'Location' headers "Inf-S" and "Eff-S." There was a substantial difference between the influent BOD results (145 vs 230). This suggests that the sampling technique presently used by the operator does not always produce representative samples.

Table 4 - Results of Bioassays on Effluent - Sumas WWTP, 9/91.

Rainbow Trout	*(Oncorhynchus mykiss)*			96-hour acute
concentration		# of live organisms		Percent
(%vol/vol)	Replicate	Initial	Final	mortality
Control	A	4	4	0
	B	4	4	0
	C	4	4	0
	D	4	4	0
100.0%	A	4	4	0
	B	4	4	0
	C	4	4	0
	D	4	4	0

LC50* = Not applicable; no mortality.

Rainbow Trout	*(Oncorhynchus mykiss)*			96-hour acute
concentration		# of live organisms		Percent
(%vol/vol)	Replicate	Initial	Final	mortality
Control	A	4	4	0
	B	4	4	0
	C	4	4	0
	D	4	4	0
65.0%	A	4	4	0
	B	4	4	0
	C	4	4	0
	D	4	4	0

LC50* = Not applicable; no mortality.

Table 4 – Results of Bioassays on Effluent, Sumas WWTP, 9/91. – Continued.

Water flea *(Daphnia pulex)* 48-hour acute

concentration (%vol/vol)	# of live organisms initial	final	percent mortality
Control	5	5	0
	5	0	100
	5	3	40
	5	4	20
100.0%	5	5	0
	5	5	0
	5	5	0
	5	4	20

LC50 = None specified; 95% survival.

Water flea *(Ceriodaphnia dubia)* 96-hour acute
7-day chronic

concentration (%vol/vol)	# of live organisms initial	final	percent mortality	ave. young per female
Control	10	8	20	15.0
6.25%	10	9	10	27.0
12.5%	10	10	0	26.9
25.0%	10	9	10	38.5
50.0%	10	9	10	52.3
100.0%	10	7	30	13.0

NOEC** = 100.0% Effluent

* LC50 means the percentage effluent lethal to one-half the test population.

** NOEC means No Observable Effects Concentration.

CONCLUSIONS AND RECOMMENDATIONS

1) The WWTP was performing well, achieving 98 percent removal of BOD_5 and TSS.

2) Two of three fecal coliform sample results exceeded permit limits. However, these were qualified results. Sampling for this parameter should be repeated the next time Ecology staff visit the WWTP. The permittee should analyze the performance of the chlorination equipment.

3) Copper, lead, and zinc were detected in the effluent, but at concentrations below water quality standards.

4) BOD_5 influent loading is approaching 85 percent of design capacity. However, loading to the aerator, when measured in terms of lbs. BOD/1,000 ft^3, appears to be well within acceptable design standards. All factors which contribute to a determination of design capacity should be revisited before the permit is reissued.

5) Nitrification and denitrification were occurring. As a result, nitrogen removal was excellent. Concentrations of phosphorus in the effluent were somewhat higher than are typically found in municipal effluent.

6) Rough calculations suggest that the volatile solids reduction in sludge was about 60%, well above the minimum of 38%. No determination was made of whether the federal requirements for pathogen reduction were being met. Sampling and calculations should be repeated by the permittee using flow weighted average data collected over a one or two month period to determine if the sludge is adequately stabilized for land application. This effort should include an analysis of sludge age in the ditch.

7) No toxicity was indicated by the four acute and one chronic bioassays run on the effluent. LC_{50}s and the NOEC indicated either no mortality or results that were statistically insignificant.

8) The operator's present sampling procedure, which involves hand composites of influent and effluent, is not always producing representative samples. This procedure should be replaced with 24 hour automatic composite sampling.

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Appendix A – Analytical Methods and Laboratories Used – Sumas WWTP, 9/91.

Parameter	Method used	Laboratory used
General Chemistry		
Turbidity	EPA, 1983: 180.1	Ecology; Manchester, WA
Conductivity	EPA, 1983: 120.1	Ecology; Manchester, WA
Alkalinity	EPA, 1983: 310.1	Ecology; Manchester, WA
Hardness	EPA, 1983: 130.1	Ecology; Manchester, WA
Chloride	EPA, 1983: 330.0	Ecology; Manchester, WA
TS	EPA, 1983: 160.3	Ecology; Manchester, WA
TNVS	EPA, 1983: 160.4	Ecology; Manchester, WA
TSS	EPA, 1983: 160.2	Ecology; Manchester, WA
TNVSS	EPA, 1983: 160.4	Ecology; Manchester, WA
% Solids	APHA, 1989: 2540G	Ecology; Manchester, WA
% Volatile Solids	APHA, 1989: 2540G	Ecology; Manchester, WA
BOD5	EPA, 1983: 405.1	Water Mgmt. Lab; Tacoma, WA
TOC (water)	EPA, 1983: 415.2	Sound Anal. Svcs.; Tacoma, WA
NH3-N	EPA, 1983: 350.1	Ecology; Manchester, WA
NO3+NO2-N	EPA, 1983: 353.2	Ecology; Manchester, WA
Nitrogen – Total (TPN)	Valderrama, 1981	Ecology; Manchester, WA
T-Phosphate	EPA, 1983: 365.2	Ecology; Manchester, WA
Phosphorus – Ortho	EPA, 1983: 365.3	Ecology; Manchester, WA
Oil and Grease	EPA, 1983: 413.1	Water Mgmt. Lab; Tacoma, WA
Fecal coliform	APHA, 1989: 9222D	Ecology; Manchester, WA
F-Coliform MPN	APHA, 1989: 9221C	Ecology; Manchester, WA
F-Strep MPN	APHA, 1989: 9230B	Ecology; Manchester, WA
Metals		
Cadmium	EPA, 1984:200.7	Ecology; Manchester,WA
Copper	EPA, 1984:200.7	Ecology; Manchester,WA
Lead	EPA, 1984:200.7	Ecology; Manchester,WA
Zinc	EPA, 1984:200.7	Ecology; Manchester,WA
Bioassays		
Rainbow trout	EPA, 1985	Ecology; Manchester,WA
Ceriodaphnia dubia	EPA, 1989a	Ecology; Manchester,WA
Daphnia Pulex	EPA, 1985	Ecology; Manchester,WA